STRUCTURE OF ALPINE PLANT COMMUNITIES NEAR KING'S PEAK, UINTA MOUNTAINS, UTAH

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Abstract.— A study was made at 18 sites with elevations between 3512 and 3768 m in the Uinta Mountains, Utah. Sites were small in extent but typified vegetation patterns found in the Uintas. Standing crop, species composition (based on dry weight), and values for several physical parameters were determined at each site. Simple linear regressions performed between the various biotic and abiotic characters revealed significant relationships between the characteristics of rocks visible at the surface (the number, size, and variation in size) and vegetation cover. This relationship was probably due to the burial of rocks as a region became vegetated. Bray and Curtis ordinations performed on the data indicated that there were several factors which influenced the species composition but that no single factor dictated the vegetational pattern.

The Uinta Mountains of northeastern Utah are the largest east-west trending range in North America. Much of the alpine and subalpine regions of the range are dominated by members of the Cyperaceae (sedges). These sedge-dominated regions may be placed into two categories: wetland areas and upland areas. In a separate paper (Briggs and MacMahon, in preparation) we discuss the structure of some sedge-dominated wetlands in the Uintas. In this paper we discuss the higher plant composition, standing crop, and physical factors at 18 upland sedge-dominated sites within a small region in the vicinity of King's Peak.

Hayward (1952) published a general description of the vegetation of the Uintas. Lewis (1970) studied the Uinta alpine vegetation and described five alpine communities. Lewis felt that exposure, snowpack, and moisture were important in determining the structure of these communities. Several other workers have considered these factors to be important in determining plant community structure in North American alpine regions (Marr 1961, Holway and Ward 1963, Bliss 1963, Webber et al. 1976). Flock (1978) showed that these factors were also important to the distribution of lichens and bryophytes. Alpine areas also show variation on a smaller scale, with distinct vegetation regions on the order of 20 m^2. Some of these changes can be attributed to microtopographical variations (Billings 1979). In this study we describe the plant associations within a small area (< 1 km^2) of the Uintas and topographical and soil factors associated with these areas.

Study Area

The Uinta Mountains are in northeastern Utah at a latitude of 40°45′ N. They trend almost directly east-west for a distance of 80 km (110–111°W). Bedrock throughout most of the alpine portion of the range is a Precambrian quartzite. Because of the inaccessibility of the Uinta alpine zone (i.e., there are no roads), there are few studies of the area. Climatic data from the region are few but probably are similar to those for the Front Range of the Colorado Rockies. Lewis (1970) estimated precipitation to vary between 85 and 125 cm, with approximately three-fourths of this falling as snow.

We studied an area near King's Peak in the central part of the range, at elevations of 3512–3768 m (11,560–12,300 ft) (Fig. 1). Much of this region consists of cliffs, debris slopes, and felsenmeere, but parts contain a well-developed alpine turf. Cryopedogenic processes are operating in the region, as

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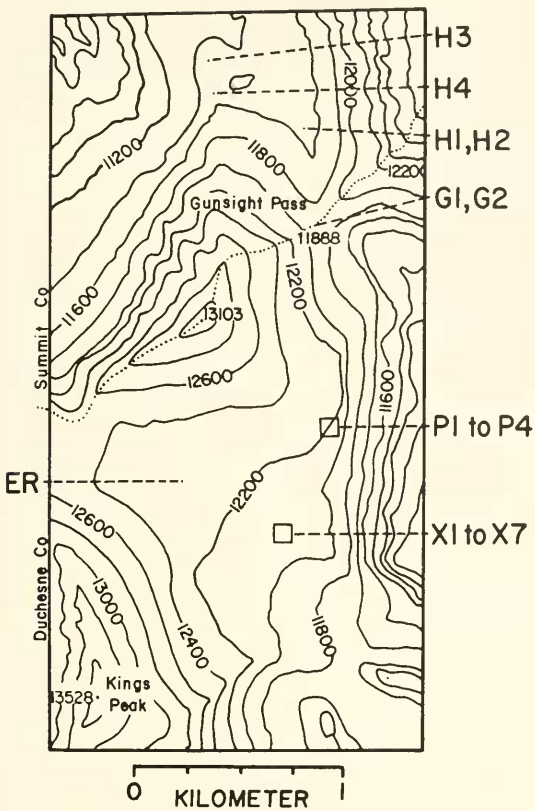

Fig. 1. Map of the vicinity of King's Peak, showing the location of the 18 study sites.

evidenced by stone circles and stripes. Although the vegetated regions often appear homogeneous from a distance, close inspection reveals changes in vegetation, microtopography, and rockiness. The 18 study sites were chosen to illustrate several regions distinguishable to the eye that commonly occur within this small area. These sites are typical of the alpine vegetation of the Uintas in general. It should be emphasized that the size of the study sites was small (30–100 m^2) in comparison to many phytosociological studies but reflected a scale of vegetational change found in the region.

Methods

Nomenclature follows Cronquist et al. (1977) and Holmgren and Reveal (1966) except for *Carex nelsonii* Mkze., which the aforementioned authors have grouped with *Carex nova* L. H. Bailey. We retain *Carex nelsonii* as a separate species based on discussions with Mont Lewis and Arthur Holmgren and on our own observations.

Each alpine site was sampled along a single transect. The boundaries of the area sampled were subjectively set. The initial sample point was randomly chosen; subsequent sample points were regularly spaced. At each sampling point a 20 × 50 cm frame was put down and all the vascular plant material within the frame was clipped at ground level. If possible, the clipped plants were immediately sorted to species and placed in paper bags. Most samples could not be sorted in situ because of the wind. Samples not sorted in the field were placed in paper bags and sorted in the lab. After sorting, all samples were air dried for at least two months and then placed in a drying oven (40 C) for 24 hours and then weighed. Ten samples were collected from each alpine site. Field notes were taken as to the contents of each bag collected. The vegetative identification of *Carex* spp. was not as formidable as might be expected. There were only five species found on the sites (only three were common), rarely did more than two species occur in a single sample bag, and both *Carex paysonis* Clokey and *C. rupestris* All. are quite distinct vegetatively.

One problem facing investigators in both Colorado and Utah is the separation of *Carex elynoides* Holm. and *Kobresia bellardii* (All.) Degland. These species are vegetatively very similar, occupy the same habitat, and fruit infrequently. Separation is easy if fruiting material is present. In all samples having vegetation of the *Carex elynoides-Kobresia bellardii* type each individual fruiting stalk was carefully examined (there were from 0–25 fruiting heads/sample). All the heads examined were *Kobresia bellardii*, and, therefore, all the vegetation of the *Kobresia-C. elynoides* type was considered to be *Kobresia bellardii*.

At each site elevation, slope and aspect were measured. Soil samples were dug on 15 September 1975. Soils were sampled at a depth of 5–10 cm, a depth approximating the middle of the rooting zone. Values for nitrate nitrogen, available phosphorus, and cation exchange capacity were determined by the Utah State University Soil and Water Analysis Laboratory. Gravimetric percent water was determined by weighing soil samples before and after drying (percent = fresh weight–dry weight/dry weight). The pH was determined using a pH meter. A textural analysis was performed by shaking the soils in a series of sieves for five minutes. The percentage of soil, by weight, found in each of the sieves was recorded. A parameter for soil texture was calculated for the samples by giving each size class a weighting factor (1–6) and multiplying the percentage of soil in each size class by the weighting factor, then summing the values for the six size classes. To obtain absolute values for comparison to the relative texture values, the finest and coarsest samples were analyzed by the Utah State University Soil and Water Analysis Laboratory.

The percent cover of soil, rocks, vascular plants, saxicolous lichens, and terricolous lichens was determined by using the line intercept method (Mueller-Dombois and Ellenberg 1974) on three 1 m lines within the sites. The number and average surface area of the rocks encountered in these transects were recorded.

Ordination methods were used to relate the study sites to each other and to elucidate the factors important in structuring the communities. The indirect gradient analysis of Bray and Curtis (1957) was chosen in hope of determining the coenoclines operating in these sedge-dominated regions. A computerized version of the Bray and Curtis method was used. Stands were compared, using the percentage similarity index (PS) where:

$$PS = \frac{2\sum^{i} \min (Pij, Pik)}{\sum^{i} (Pij + Pik)} \times 100$$

Pij = measurement of the ith species in the jth stand.

Pik = measurement of the ith species in the kth stand.

The importance of each species was indexed by its aboveground standing crop (dry weight).

Using the numerical values which depict each site's placement on the ordination axis, simple linear regressions were run relating the vegetational relationships of the sites (as depicted in the values for the ordination axes) to the various measured environmental parameters.

Possible relationships among the various parameters measured at each site were studied through the construction of a correlation matrix that gave correlation coefficients for simple, linear regressions run between each pair of site parameters.

RESULTS AND DISCUSSION

The results of the line intercept analysis (Table 1) show the cover percentage in each

TABLE 1. Standing crop and cover values for the alpine sites.

Site	Standing crop (g/m^2)	Vegetational cover (%)	Soil cover (%)	Rock cover (%)	Soil covered by lichens (%)	Rock covered by lichens (%)
H1	157	99	0	0	–	–
H2	193	99	0	0	–	–
H3	66	66	34	0	9	–
H4	61	73	26	0	–	–
P1	37	20	28	49	31	41
P2	79	67	20	11	10	3
P3	67	61	23	20	20	45
P4	78	56	46	3	49	47
X1	73	79	18	1	7	0
X2	46	37	32	36	0	14
X3	125	91	7	3	0	67
X4	56	24	55	16	0	0
X5	99	63	34	4	43	0
X6	58	39	30	30	13	73
X7	75	35	45	25	47	60
G1	143	72	28	0	11	–
G2	206	99	–	–	–	–
ER	75	–	–	–	–	–

of three categories. Vegetation cover varied from 20 to 99 percent. The amount of surface covered by rocks varied from 0 to 55 percent. The percent of available rock and soil covered by lichens is also shown in Table 1.

The values for the physical parameters measured at each site are given in Table 2. The soil data reflect a lack of soil development. All of the sites were deficient in nitrate nitrogen with values ranging from 0.1 to 3.3 ppm. Phosphorus was also low, ranging from 1.9 to 27 ppm. These values are lower than the 11.2 to 42 ppm values reported by Nimlos and McConnell (1965) for Montana alpine soils. The cation exchange capacity of these soils ranged from 5.3 milliequivalents/100 g soil to 33.3 me/100 g soil. The cation exchange capacity seems high, especially when considering the lack of clay in the soil (see below). The high cation exchange capacity is probably due to the presence of organic matter in the soil resulting from slow decomposition rates.

The texture of all the soils was sandy. Manual sifting gave values of 95 and 100 percent sand. Automated sifting of the two extremes based on our texture scale gave values of 63 and 85 percent sand. These values would define soils classified from sandy loams to loamy sands (Donahue et al. 1971). [The finest soils might be classified a sandy clay if the nonsand fraction (37 percent) were assumed to be more than 18 percent clay. This appears unlikely.] These soils are considerably coarser than most other alpine soils studied. Marr (1961) described soils of the Colorado Front Range which have only 35–59% sand. Nimlos and McConnell's study (1965) of Montana alpine soils describes textures much finer than those of the Uintas. A lack of soil development is expected in any alpine area due to the low temperatures and short growing season. The fact that the Uinta soils are even more poorly developed than other areas of alpine in the western United States is probably due to the quartzite bedrock which weathers slowly and results in a sandy soil that is low in nutrients.

It is obvious that cryopedogenic processes are operating in the Uintas (Lewis 1970). Because these processes result in a size sorting of rocks, it was hoped that values for the following parameters might reflect a particular stage of the cryopedogenic process: mean surface rock size (cm^2); number of rocks visible at the surface; and the normalized variation in surface rock size. Values for these parameters varied at the alpine sites (Table 2). Some of the variation was related to vegetation. It was noted that there appeared to be two extremes in community structure that were related to surface rock characteristics.

TABLE 2. Values for soil parameters, slope, and surface rock characteristics for the alpine sites.

Site	P (ppm)	N (ppm)	CEC (meq/ 100g)	pH	Water (%)	Texture[1]	Slope (%)	Rocks (#)	Rock size (cm^2) ($\bar{x}$)	Rock size ($s/\bar{x}$)
H1	9.6	0.1	11.6	4.9	19	245	8	0	–	–
H2	1.9	0.1	5.3	5.4	9	251	8	0	–	–
H3	5.6	0.3	14.9	5.5	17	252	0	–	–	–
H4	9.1	0.3	12.6	4.2	16	239	30	0	–	–
P1	10.0	3.1	17.4	6.0	20	308	0	85	4.8	1.2
P2	11.0	1.0	17.9	5.6	14	298	12	0.7	9.5	1.1
P3	7.5	1.9	13.5	5.7	20	347	25	36	8.1	0.9
P4	8.4	0.7	14.8	5.5	22	331	4	6	17.4	0.9
X1	13.0	1.7	23.8	5.4	28	320	15	0	241.3	0.9
X2	7.3	3.3	16.2	5.0	26	352	11	30	73.4	2.1
X3	14.0	1.2	32.3	4.8	21	374	5	1	743	0.8
X4	27.0	3.4	20.4	5.1	40	322	8	34	8.0	1.7
X5	9.3	2.4	25.8	5.1	28	366	12	1	584	1.3
X6	8.0	1.0	19.2	4.6	29	348	12	4	142	0.7
X7	3.2	0.3	10.2	4.9	16	334	12	16	35	1.6
G1	13.0	0.7	21.4	6.3	22	374	11	0.3	244	0.7
G2	4.2	0.1	9.8	4.6	10	239	52	0	–	–
ER	0.0	–	–	–	18	–	4	0	–	–

[1]Texture values are on an arbitrary scale. Finer soils have a higher value. See text.

Some areas had a very dense turf with a few large rocks visible at the surface. At the other extreme were areas of sparse vegetation with a large number of rocks of a variable size visible at the surface. This observation is reflected in the correlation coefficients (Table 3), where there were several significant correlations between rock characteristics and standing crop and cover values.

The relationships between surface rock characteristics and vegetation may partially explain some of the correlations between surface rock characteristics and soil parameters. For example, texture was significantly ($p < .05$) related with mean rock size (Table 3). The finest soils were found in areas with large rocks. These were areas with high biomass, where organic matter was added to an otherwise very sandy soil.

There are at least two possible explanations for the significant relationships between surface rock characteristics and vegetation (Table 3). These relationships could reflect a link between cryopedogenesis (that will affect surface rock characteristics) and vegetation, a situation shown by Johnson and Billings (1962). A second possibility is that the relationship between vegetation and surface rock characteristics is due to a simple process of burial of all but the largest rocks as a turf develops. If the surface rock characteristics were reflecting a cryopedogenic process, one would expect a relationship between surface rock characteristics and the percentage of rocks and soil covered by lichens (cryopedogenesis causing instability in rock and soil surfaces and thus a lack of lichens). Because there was no significant relationship between surface rock characteristics and the percentage of lichens on the soil or rocks, we feel that the interaction between vegetation and the surface rock characteristics involves burial.

The peak aboveground biomass varied from 37 to 206 g/m² (Table 1). Lewis' (1970) data on the Uinta alpine zone gave standing crop values ranging from 48.2 g/m² for *Geum*-sedge communities to 83.4 g/m² for *Carex-Kobresia*-grass communities. The Uinta standing crop values are lower than those of other regions of North American alpine tundra. Scott and Billings (1964) reported standing crop values ranging from 14 to 348 g/m² in the Beartooth Mountains of Wyoming; most sites ranged from 100 to 200 g/m². Thilenius (1975) reported an aboveground standing crop value of 223 g/m² in the Medicine Bow Mountains of Wyoming. The low standing crop values in the Uintas may be attributed to the poor soil development. One

Table 3. Correlation matrix for site parameters giving the r value for a simple linear regression between each pair of factors. An asterisk (*) indicates significance at the 0.05 level.

	P	N	CEC	pH	Water %	Texture	Rocks #
P	1	.35	.47	–.14	.62*	.17	–.23
N		1	.22	.25	.58*	.33	.53
CEC			1	–.20	.22	.45	–.32
pH				1	–.22	–.21	.31
Water %					1	.21	–.01
Texture						1	–.19
Rock #							1
Rock size x̄							
s/x̄							
Standing crop							
Vegetational cover							
Soil cover							
Rock cover							
Slope							
Soil covered by lichens %							
Rock covered by lichens %							

possibility is that the sandy texture of these soils allows for little water storage, thereby increasing the chance of drought-stress. Most of the areas we studied had little winter snowpack and were dependent on summer thunderstorms as a source of water. Such thunderstorms are common in the Uintas, but our observations show that the region sometimes goes without rainfall for over a week, in which case the low water-storage capacity of these soils might be important. Data on rainfall and soil water potential would be needed to see if drought is indeed an important factor. Another way in which the poor soil development might affect aboveground standing crop in the Uinta alpine is through low nutrient levels. Our data did not suggest a relationship between nutrient levels and standing crop (Tables 1, 2, and 3), nor did it show that the Uinta alpine was substantially lower in nutrients than some other alpine areas. Our soil sampling was not extensive, and perhaps more sampling of the nutrient levels in these soils would show them to be critical.

Forty-two plant species were sampled on the 18 sites (Table 4). The number of species on any one site varied from 8 to 17. Of the 42 species, 16 were dominants (having 5 percent or more of the aboveground standing crop for a site). The number of dominants at any one site varied from 2 to 5.

Most of the dominant species of the Uinta alpine are dominants of other areas of western alpine regions. *Geum rossii* (R.Br.)Ser. and *Carex rupestris* dominate portions of the Beartooth Range of Wyoming (Scott and Billings 1964) and Niwot Ridge in Colorado (Marr 1961). *Kobresia bellardii* is common on Niwot Ridge but absent in Wyoming. *Carex paysonis* is the only dominant in the Uintas that is not a common dominant in other west ern alpine regions.

The sites we studied fall into three of the communities that Lewis (1970) described: *Carex rupestris* and cushion plant communities, *Geum*-sedge communities, and sedge-grass communities. As Lewis points out, these communities are far from discrete and several of our sites are "transitional" between his basic community types. Moreover, because of the limited size and relative homogeneity of the area we studied, any worker studying the vegetation of the whole range probably would have lumped the entire region into one community: *Geum*-sedge. Close study of this area reveals variation both in vegetation and in several physical factors. In an effort to relate the variation in physical factors with variation in vegetation, and also to better

Table 3 continued.

Rock size $\bar{x}$	$s/\bar{x}$	Standing crop	Veg. cover	Soil cover	Rock cover	Slope	Soil with lichens %	Rock with lichens %
.20	.16	.26	.13	.18	–.41	–.36	–.50	–.65°
.03	.55°	.15	–.38	.09	.37	–.47	–.23	–.55°
.89°	–.13	.59°	.54°	–.53°	–.41	–.48	–.30	–.46
–.31	–.29	.14	.12	–.10	–.10	–.45	.20	–.27
.02	.32	–.22	–.33	.45°	.02	–.46°	.23	–.39
.61°	.33	.54°	.17	–.21	–.02	–.20	.16	.46
–.45	.41	–.61°	–.69°	.10	.81°	–.21	–.13	.20
1	–.10	.71°	.60°	–.51	–.42	.01	.01	.50
	1	–.33	–.56°	.34	.52	.05	–.51	–.13
		1	.74°	–.38	–.70°	.56°	.02	–.15
			1	–.66°	–.81°	.56°	–.17	–.10
				1	.12	.02	.11	.69°
					1	–.10	.15	.38
						1	–.21	.17
							1	.62°
								1

compare the different sites, we utilized ordination techniques. Ordination techniques order stands on the basis of their vegetational similarities. Each stand is given a numerical value on one or several axes. The axis values indicate the site's position in a vegetational space (Beals 1973). In the Bray and Curtis ordination, the end stands of the first axis (the x-axis) are the two stands with the lowest percent similarity. All the other stands are arranged relative to the first two. Stands that have a high percent similarity have similar x-axes values. The second axis (the y-axis) is produced by selecting two stands in the center of the x-axis and making them end stands. Again, all stands are arranged relative to these end stands.

Ordinations of all 18 sites were similar if importance values from all species were used or if only the importance values from the dominant species were used. An all-species ordination is illustrated (Fig. 2). ER is clearly separated in the x-axis and H1, H2, H4, and G2 on the y-axis. This separation was expected because these sites were dominated by species not present on other sites: *Carex nelsonii* on ER, and *C. paysonis* on H1, H2, H4, and G2.

Although a significant correlation ($r = 0.63$) was found between the percent water in the soil and a site's position on the x-axis of these ordinations (Table 5), this correlation is due solely to the site ER. This site was widely separated in the ordination and

TABLE 4. Species found on the alpine sites. Asterisks (°) indicate that the species constituted greater than 5 percent of the aboveground standing crop.

	H1	H2	H3	H4	P1	P2	P3
Geum rossii (R. Br.) Ser.	°	°	°	—	°	—	—
Carex paysonis Clokey	°	°		°			
Deschampsia cespitosa (L.) Beauv.	°	—		—			—
Polygonum viviparum L.			—	—	—	—	
P. bistortoides Pursh	—	—	—				—
Artemisia scopulorum A. Gray	—			°			
Potentilla spp.	—	—	—	—			
Caltha leptosepala DC.	—			—			
Poa fendleriana (Steud.) Vasey	—						
Festuca ovina L.	—	—	—	—			
Erigeron simplex Greene		—	—	—	—	—	—
Agropyron scribneri Vasey		—					
Trisetum spicatum (L.) Richt.		—					
Poa alpina L.		—					
P. rupicola Nash		—		—	—	—	
Carex rupestris All.			°		°	°	°
Eritrichium nanum (Vill.) Schrad.			—				
Trifolium parryi A. Gray			—		—	—	°
Carex pseudoscirpoidea Rydb.			—				
Hymenoxys grandiflora (Torr. & Gray) Parker			—			—	—
Smelowskia calycina C. A. Meyer							
Draba spp.			—				
Silene acaulis L.			—		—	—	—
Kobresia bellardii (All.) Degland					°	°	—
Arenaria obtusiloba (Rydb.) Fernd.				—	—		—
Paronychia pulvinata A. Gray							—
Danthonia intermedia Vasey							—
Agrostis humilis Vasey							
Salix nivalis Hook.				—			
Castilleja pulchella Rydb.							
Luzula spicata DC.				—			
Carex misandra R. Br.							
C. nelsonii Mkze.							
Lloydia serotina Reichb.							
Eriophorum chamissonis C. A. Meyer							
Antennaria alpina (L.) Gaertn.				°			
Juncus parryi Engelm.				°			

had four times the percent water of any other site (Table 2). Elimination of this site reduced the r to 0.03. In a similar manner a site's position on the y-axis of the 18 site ordinations was significantly associated with texture, cover values, and standing crop. These represented relationships between these parameters and the sites H1, H2, H4, and G2. To see if specific trends for the other sites might become apparent, ordinations were run with 17 sites (eliminating ER) and with 13 sites (eliminating ER and H1–H4). Although there were some significant relationships between site parameters and ordination axis values, these represented separation of end stands from the rest of the sites and not general trends within the data as a whole.

The vegetation of these regions does not appear to be ordered on any of the site parameters we studied, although there do appear to be specific relationships with certain sites (e.g., nearby springs producing sites like ER, slopes producing sites like G2). The variation in the vegetation of the region as a whole is dependent upon the tolerances and capabilities of individual species (Gleason 1939). For example, the distribution of *Kobresia bellardii* is associated with areas of low snow accumulation (Bell and Bliss 1979). In the alpine areas that we studied it appears that a variety of different factors are limiting the distribution of plant species and that no one factor is critical to the distribution of several species as a group.

Table 4 continued.

P4	X1	X2	X3	X4	X5	X6	X7	G1	G2	ER
°	°	°	°	—	°	°	°	°	°	—
									°	
	—		—	°			—	—	—	°
—			°	°	—	—	°	—		—
—	—		—	—						
	—	—	—	°		—	°		—	
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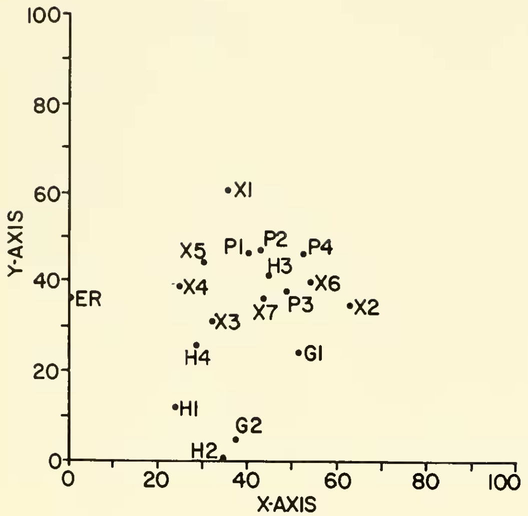

Fig. 2. Ordination of all 18 sites studied, using all species sampled.

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Table 5. R values for simple linear regressions ran between ordination axes and site parameters. An asterisk (°) indicates significance at the 0.05 level.

	All 18 sites			
	All species		Important species	
Factor	x	y	x	y
Phosphorus	.37	.29	.26	.01
Nitrogen	.20	.43	.25	.37
Cation exchange	.12	.12	.04	.36
pH	.34	.27	.53°	.36
Water (%)	.63°	.31	.67°	.18
Texture	.39	.51°	.37	.43
Rocks #	.01	.08	.01	.23
Rock size x̄	.45	.28	.32	−.25
Rock s/x̄	.04	.04	.07	−.27
slope	−.18	−.67	.17	.41
Standing crop	.14	−.82°	.11	−.71°
Veg. cover	.38	−.59°	.20	−.49
Soil cover	.16	.56°	.18	.59°
Rock cover	.38	.29	.17	.44
Soil covered by lichen (%)	−.21	−.05	−.26	−.18
Rock covered by lichen (%)	.38	.19	.22	.15

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Table 5 continued.

17 sites				13 sites			
All species		Important species		All species		Important species	
x	y	x	y	x	y	x	y
–.14	.14	–.39	.27	–.28	.28	–.76	–.37
.24	–.20	.02	.52°	.01	–.01	–.23	.11
.13	.37	–.02	.42	–.21	–.17	.01	.40
.59°	–.38	.49	.35	–.18	.13	.12	.16
.02	–.16	–.08	.50	–.08	.08	–.60°	–.23
.62°	–.39	.14	.53°	–.10	–.15	.18	.26
.21	.01	.06	–.15	.25	–.15	–.45	.26
–.46	–.07	–.23	–.29	–.17	–.26	.30	.37
.25	.17	–.50	–.01	.19	–.29	–.27	–.20
–.39	.35	.01	.52°	.01	.52°	.13	.55°
–.23	.38	–.23	–.85°	–.48	–.01	.21	.22
–.36	.36	–.14	–.72°	.09	.22	.32	.36
–.18	.08	–.05	–.08	–.05	–.08	.58°	.37
.26	.08	.26	–.21	.26	–.21	.16	.05
.35	–.21	–.35	–.17	.01	–.55°	–.23	.22
–.24	–.49	.07	–.86°	–.23	.28	–.19	.58°